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## **Use of the Forest Disturbance Mapper (FDM) to detect and evaluate gypsy moth defoliation within the Allegheny National Forest**

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### ***MODIS Satellite Data***

During the late spring and early summer of 2013 we used moderate resolution imaging spectroradiometer (MODIS) data to assess an unfolding disturbance event on the Allegheny National Forest in northwest Pennsylvania. We acquired a sequence of MODIS and normalized difference vegetation index (NDVI) data with a resolution of 240 m<sup>2</sup> (14.2-acre pixel) and 16-day interval composite data from the U.S. Forest Service Forest Health Technology Enterprise Team online Forest Disturbance Mapper website:

<http://foresthealth.fs.usda.gov/portal/Flex/FDM?dL=0>

In FDM we utilized the 3-Year Real Time Forest Disturbance (RTFD) data. The 3-Year RTFD data is a digital change detection product that compares the current RTFD greenness (derived from NDVI) to a 3 year baseline of greenness. RTFD is designed to detect short term defoliation forest disturbance in deciduous forests such as that caused by gypsy moth.

We also used the 240 meter 3-Year Persistence of Disturbance data. Persistence of Disturbance is created by combining both the temporal persistence with the magnitude of departure from normal greenness for the latest three Disturbance Composite products. The 3-Year Persistence of Disturbance data are defined as those pixels whose greenness values are significantly below normal as compared to the 3-year baseline and have remained substantially below normal greenness for at least the latest two of the last three or all three RTFD composite periods (32 totals days).

### **The process in summary**

Using Persistence of Disturbance data our process began by monitoring FDM for the appearance of pixel groupings of potentially severe disturbance. A disturbance signature was then selected using the FDM Disturbance composite data and the Histogram Threshold Tool. The Histogram Threshold Tool enables direct interaction with the 3-year RFTD data to develop a disturbance signature that best represents the potential disturbance (reduced greenness). From these two steps

a developing disturbance was detected and points were selected for subsequent ground checking. Finally, the disturbance was delineated by drawing polygons based upon FDM **and** site visits.

### Detecting disturbance

Searching for areas indicating Persistence of Disturbance we began with a regional monitoring of FDM imagery during mid-late May of 2013. More specific targeting of Persistence occurred with the May 16-June 17 time frame of imagery where pixels of Persistence and the 3-Year RTFD data began indicating disturbance in and around the Allegheny National Forest and areas to the North. Knowing that different levels of departures from normal greenness are located at different positions within the disturbance composite histogram, we used the FDM Histogram Threshold Tool to re-class the 3-year RTFD data until we felt confident we were capturing and refining the areas of disturbance and thereby created a 'disturbance signature'. The Disturbance Composite signature we used for this event was 94-225. The combination of Persistence of Disturbance and RTFD data was sufficient to indicate areas with a significant departure in greenness and persistent disturbance (as compared to a 3 year baseline) that should be ground-checked (Figure 1). From this pool of information a set of points were selected for ground visits based upon accessibility and pixel groupings (Figure 2).

### Planning for ground checking

On-site ground visits to verify the cause of disturbance took place the last week of June 2013. Twenty-two pre-selected points were chosen based upon FDM imagery focusing upon combined cells of Persistence, RTFD, and accessibility. Latitude/longitude coordinates for pre-selected points were loaded into a GPS unit; enabling field crews to visit specific points. Site visits immediately verified the probable cause of the disturbance as **gypsy moth defoliation** and in some areas frost damage (Figure 3).

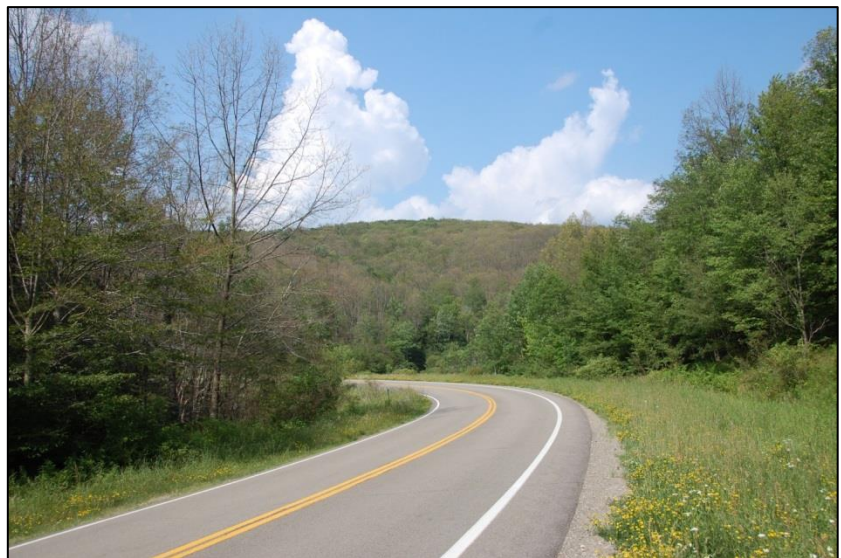


Figure 3. Gypsy moth defoliation on the Allegheny National Forest, June 2013.

In total, 46 individual points were ground checked, those pre-selected from FDM, as well as, additional points to further delineate the disturbance. Table 1 shows the results of the ground site verification. Twenty-two of the ground visits were conducted specifically at FDM Persistence cells (point locations 25-46). Of the twenty-two pre-selected FDM points, 10 were **verified as disturbance but not caused by gypsy moth defoliation**. For example, point locations 32 and 33 were verified as large shelterwood cuts (Figure 4). Points 25 and 26 showed extensive frost damage and no defoliation. Point 36 had significant beech mortality due to beech bark disease as well as some scattered gypsy moth defoliation. The relationship between the imagery and site verification of these non-gypsy moth defoliation sites is also shown in Figures 5-9.

The point verification was used in subsequent delineation of the defoliation event.



**Figure 4. Large shelterwood cut at pre-selected point 33.**

### **Drawing defoliation polygons**

Figures 10-15 illustrate the disturbance event through time as the gypsy moth defoliation occurs, peaks, and greenness returns as re-foliation takes place. Re-foliation in this event was as dramatic as the defoliation itself.

Polygons were drawn to capture the disturbance event using FDM Persistence data in combination with what we considered to be a peak Disturbance Composite (July 11-June 09) and the results of the point verification visits. These polygons totaled an estimated 105,000 acres of light to severe gypsy moth-caused defoliation. Areas of verified frost damage, or other verified disturbance were not included within the polygons. Figure 16 illustrates polygons of suspected gypsy moth defoliation within the same region of interest provided by the Pennsylvania Department of Natural Resources traditional aerial sketch-map survey conducted during June of 2013.

### **Polygons of defoliation used for subsequent egg mass surveys.**

Estimates of gypsy moth population potential for defoliation in the subsequent year are based upon egg mass surveys conducted in the late summer and early fall.

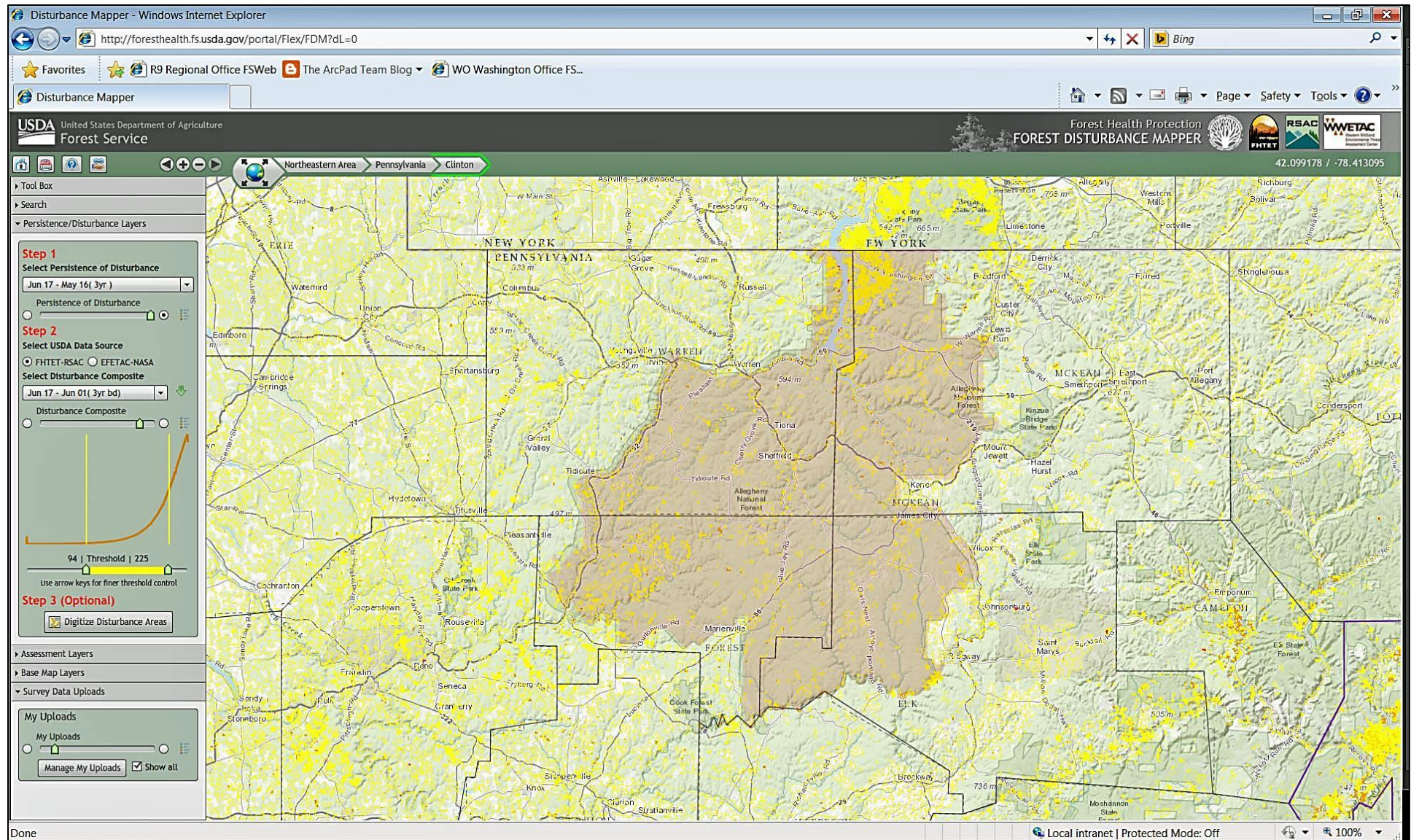
To aid in directing surveys, a composite map was created using ARCGIS®. Thematic maps representing, MODIS-derived polygon data of defoliation, Allegheny National Forest management areas and stand maps, Allegheny National Forest recreation areas, roads and trails, forest type, and oak basal area were manually overlaid to create a composite map of susceptible forest types. This composite map was then used to implement gypsy moth egg mass surveys (Figure 17).

### **Conclusion**

FDM proved to be an expedient and successful method of detecting, recognizing and capturing a disturbance event without the use of the traditional aerial survey. Persistence of Disturbance and Disturbance Compositing enabled us to focus upon a specific geographic region, monitor that region with change detection tools, verify with site visits, and ultimately use the combination of tools to draw polygons delineating the actual acreage and locations of the disturbance (gypsy moth defoliation in this case). This gypsy moth outbreak was both extensive and severe, two factors that facilitated the successful use of FDM.

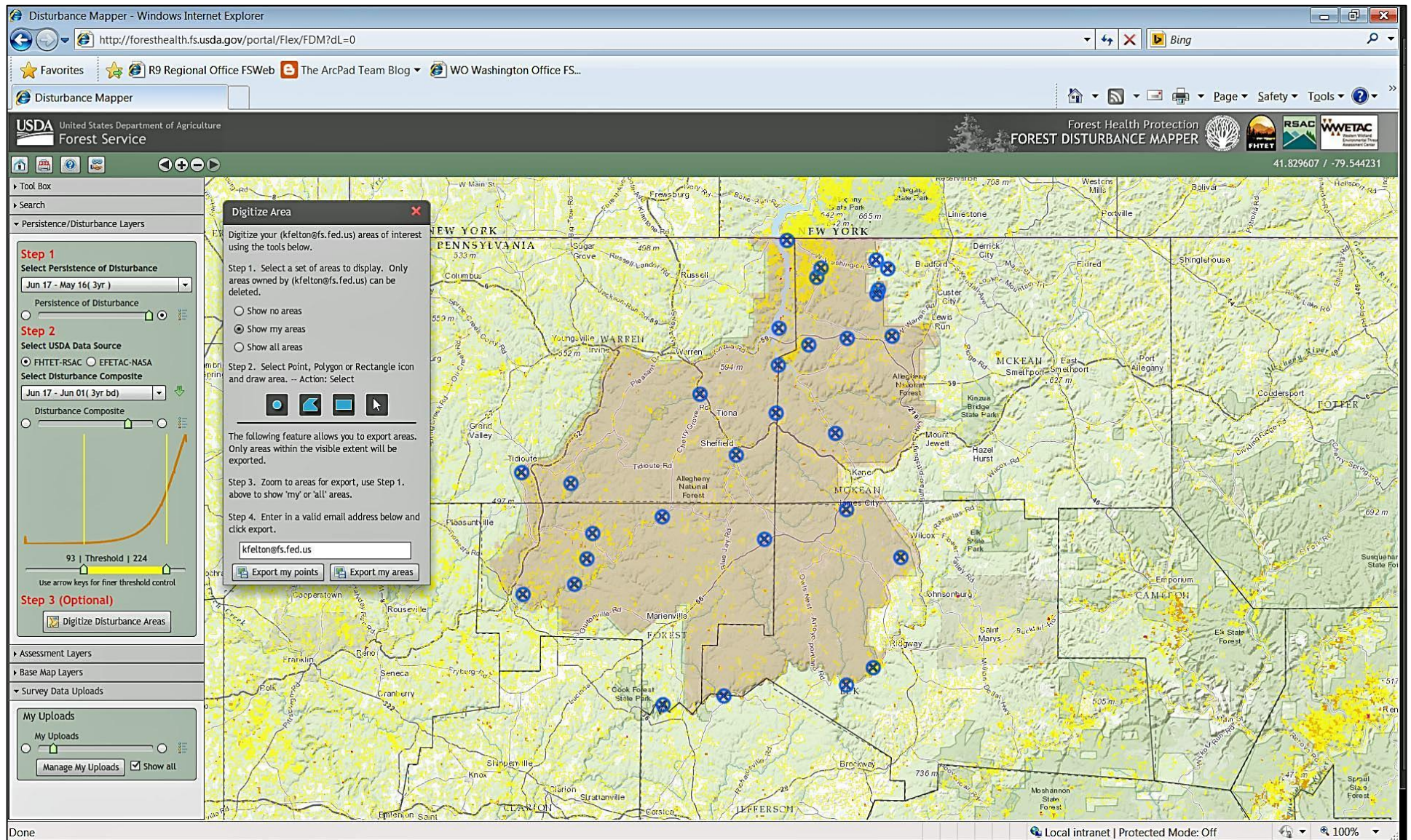


**Figure 1. First Forest Disturbance Mapper image showing when the disturbance became visible on the Allegheny National Forest, PA (3 year disturbance composite: Jun 17 – Jun 01).**





**Figure 2. The location of the pre-selected ground visit sites from the Forest Disturbance Mapper persistence cells (3 year disturbance composite: Jun 17 – Jun 01).**

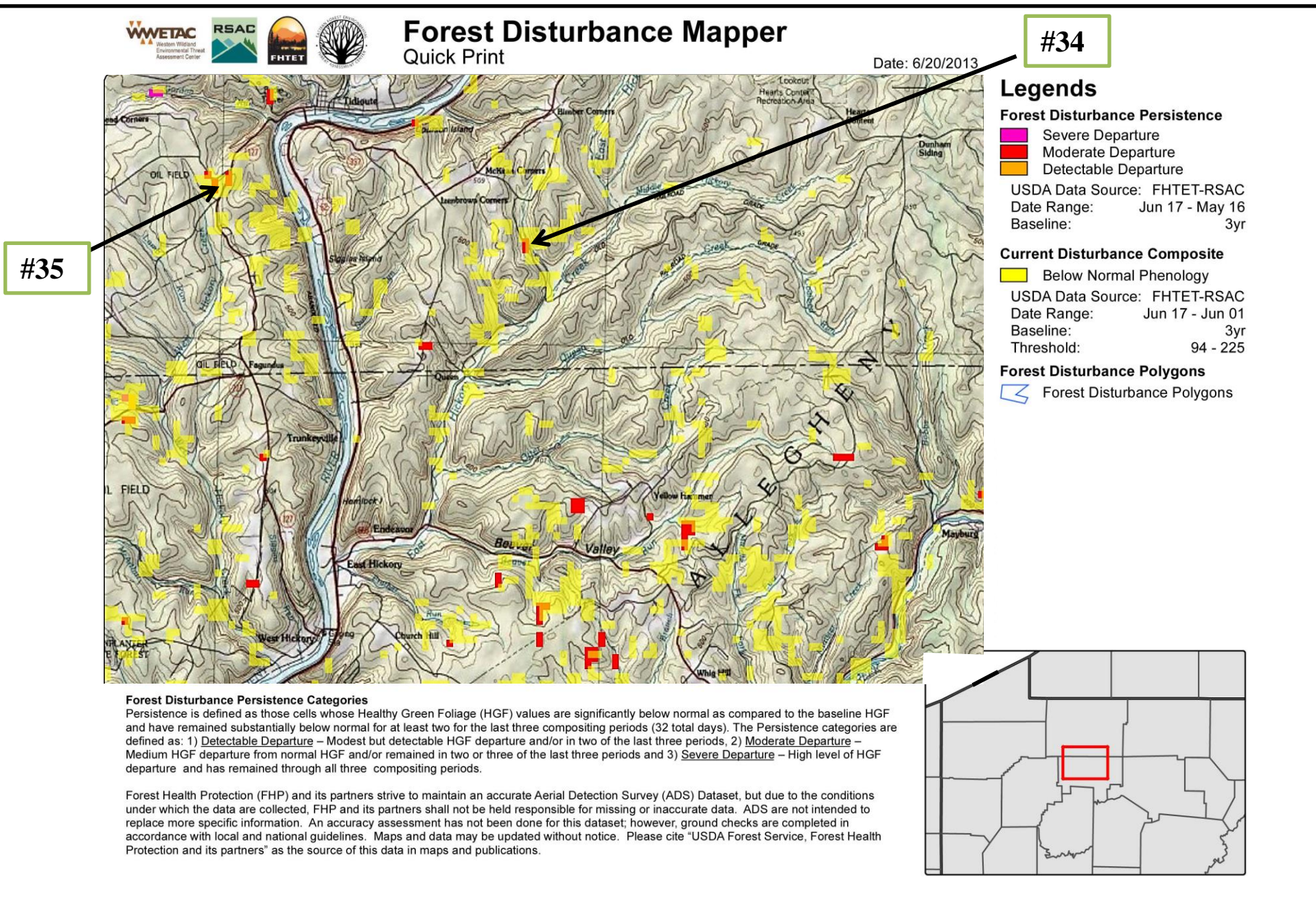


**Table 1.**

Ground truthing results for the Forest Disturbance Mapper locations on the Allegheny National Forest, June 2013		
Point Location	Point Origin	Comments
1	GPS	>50% gm defoliation - off ANF
2	GPS	100% gm defoliation, dead caterpillars - off ANF
3	GPS	scattered gm defoliation up to 50%, some dead beech, frost damage, maple, beech, oak
4	GPS	50% gm defoliation, lots of dead caterpillars
5	GPS	> 50% gm defoliation of oaks, lots of dead caterpillars
6	GPS	No defoliation, moved out of defoliation, cherry, maple, oak
7	GPS	no defoliation
8	GPS	some gm defoliation and frost damage on hillside across the river
9	GPS	gm defoliation along the ridge on other side of river
10	GPS	clear except for directly across from boat ramp -gm, frost damage
11	GPS	Heavy gm defoliation
12	GPS	100% gm defoliation
13	GPS	75-100% gm defoliation , mostly oaks, scenic trail head
14	GPS	less oak, less defoliation along road, trees are 100% defoliated
15	GPS	100% gm defoliation
16	GPS	100 % gm defoliation, mostly north of road
17	GPS	100% gm defoliation, north of lake, scattered south of lake
18	GPS	hill to the east 100% gm defoliation of oaks, across lake from here is also defoliated
19	GPS	new oil well road, extensive road construction, well, some foliage discoloration
20	GPS	shelterwood cut
21	GPS	scattered frost damage
22	GPS	moderate to heavy gm defoliation on scattered oaks, maples, oak, dead caterpillars
23	GPS	white pine mortality, interspersed hemlock
24	GPS	tionest lake, hillside adjacent to lake on west, moderate to severe gm defoliation, campground ok
25	FDM	frost damage, lots of hemlocks
26	FDM	some frost damage poor visibilty, foggy
27	FDM	scattered frost damage, moderate gm defoliation
28	FDM	mod to severe gm defoliation on scattered oaks, maple-oaks
29	FDM	moderate to severe gm defoliation
30	FDM	scattered oak gm defoliation along the river and up hiside
31	FDM	massive cutting, beech rengeneration, beech brush approx 3-5 years old, maple, beech, cherry
32	FDM	shelterwood cut, adjacent to red pine stand, thinned spruce stand
33	FDM	shelterwood cut
34	FDM	lots of hemlock, scattered beech mortality
35	FDM	thinning, white pine mostly, some white oak, no defoliation
36	FDM	some mortaltiy, BBD, some browning, some scattered gm defoliation on hillside across river
37	FDM	maple, beech, birch, no defolaition or mortality
38	FDM	shelterwood (kind of) cut
39	FDM	possible defoliation, scattered gm defoliation
40	FDM	frost damage across the lake
41	FDM	gas well activity, black cherry, some oaks with moderate to heavy gm defoliation
42	FDM	100% gm defoliation
43	FDM	100% gm defolaition , campground, old egg masses, lots of dead caterpillars
44	FDM	construction, clearing and gm defoliation on hillside to the east
45	FDM	100% gm defoliation
46	FDM	moderate gm defoliaton, scattered frost damage
GPS-collected during ground truthing trip		
FDM-points selected from Forest Disturbance Mapper for ground truthing trip		



**Figure 5. Location of disturbances on the Allegheny National Forest derived from the Forest Disturbance Mapper that proved to be disturbances other than gypsy moth defoliation - June 2013 – see Table 1 for results of all sites visited.**





**Figure 6. Location of disturbances on the Allegheny National Forest derived from the Forest Disturbance Mapper that proved to be disturbances other than gypsy moth defoliation - June 2013 – see Table 1 for results of all sites visited.**

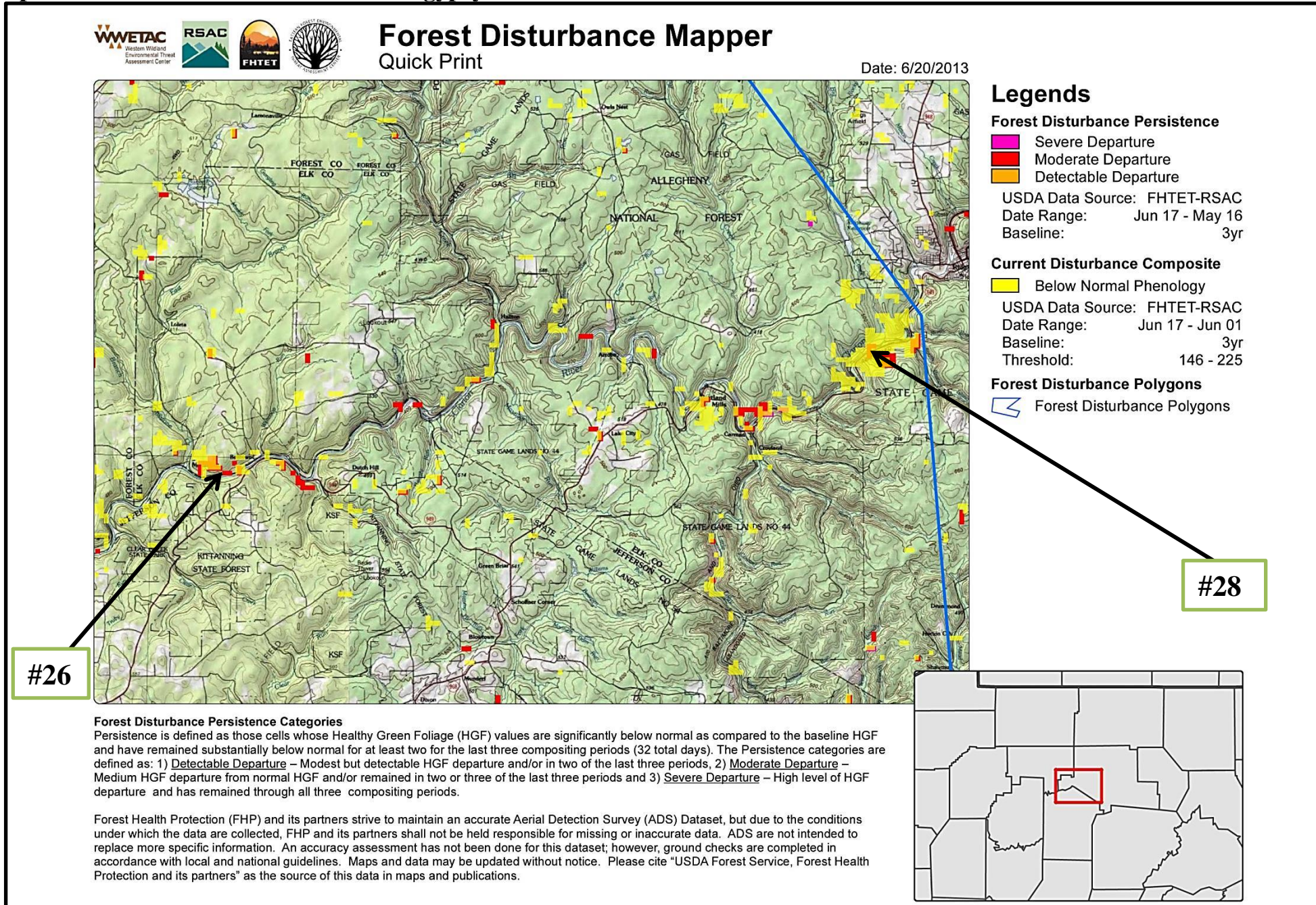
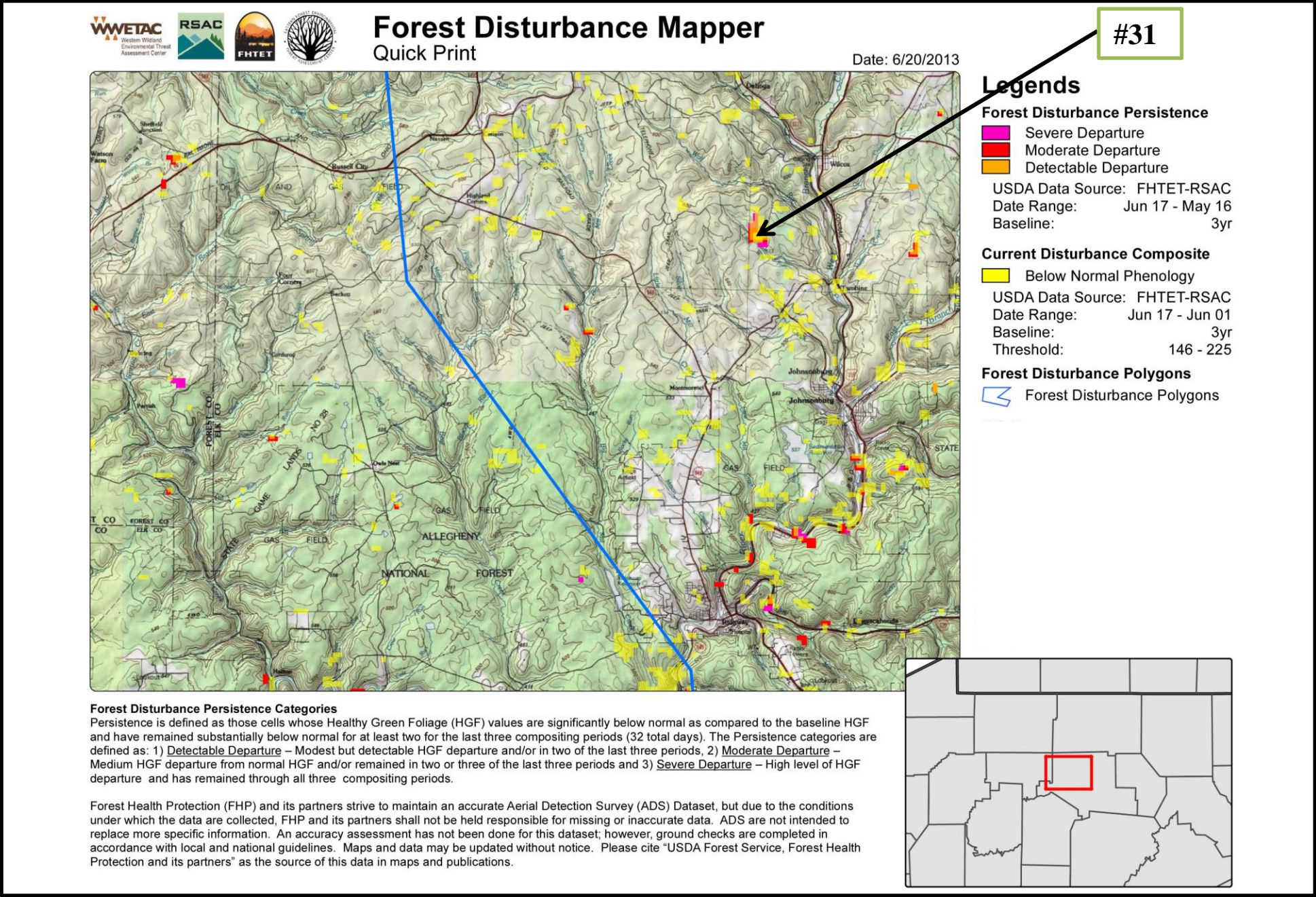


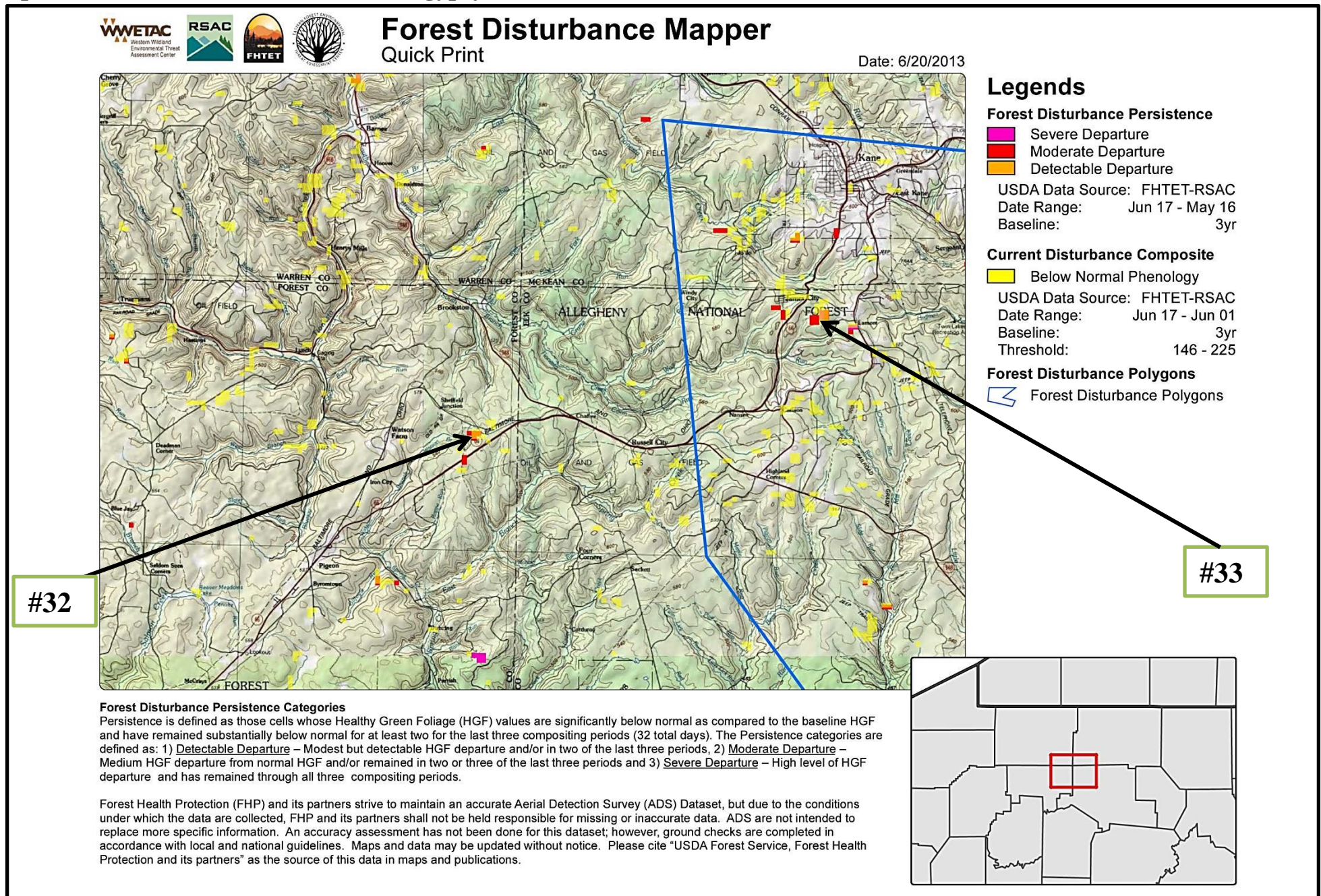


Figure 7. Location of disturbances on the Allegheny National Forest derived from the Forest Disturbance Mapper that proved to be disturbances other than gypsy moth defoliation - June 2013 – see Table 1 for results of all sites visited.



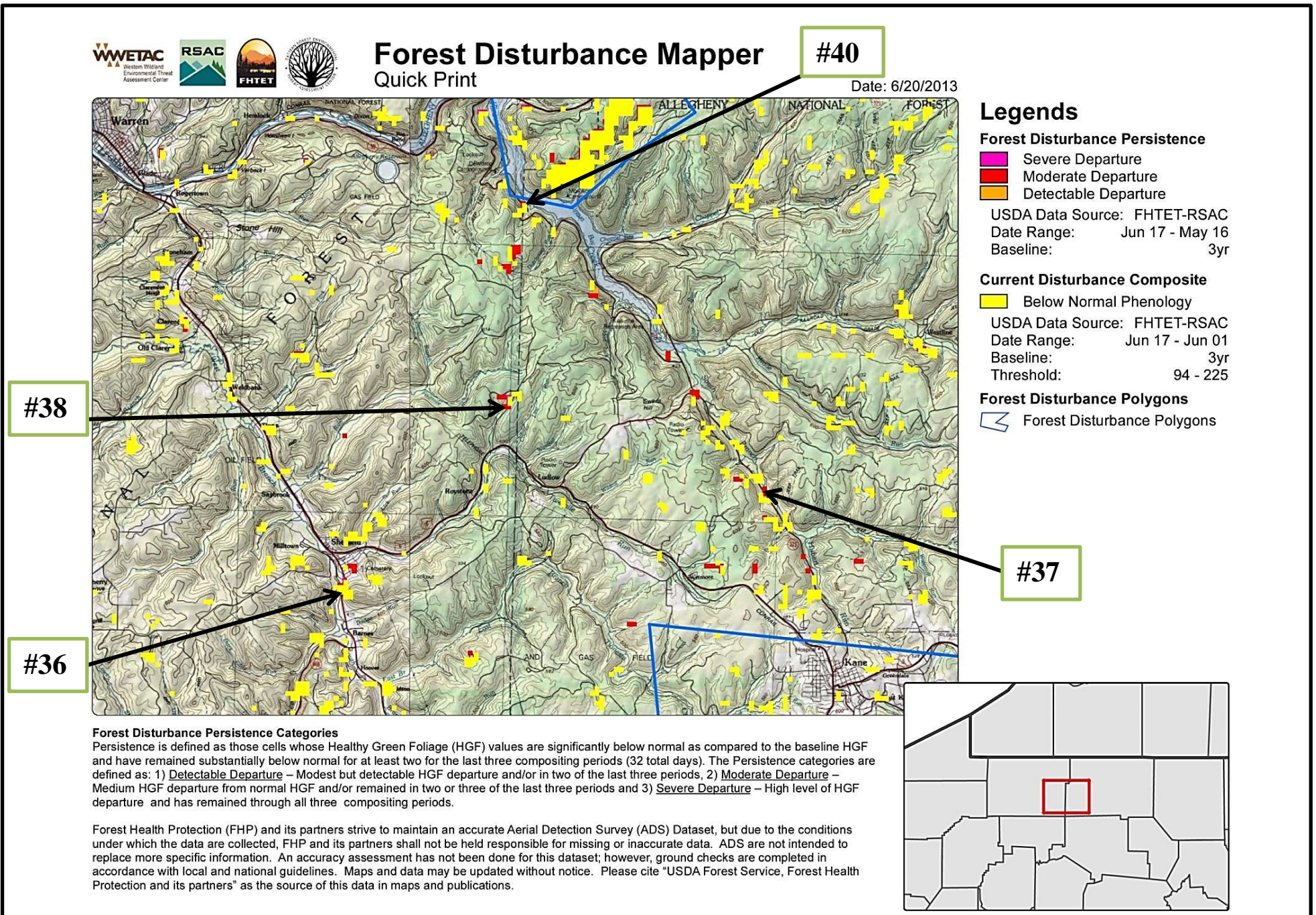


**Figure 8. Location of disturbances on the Allegheny National Forest derived from the Forest Disturbance Mapper that proved to be disturbances other than gypsy moth defoliation - June 2013 – see Table 1 for results of all sites visited.**



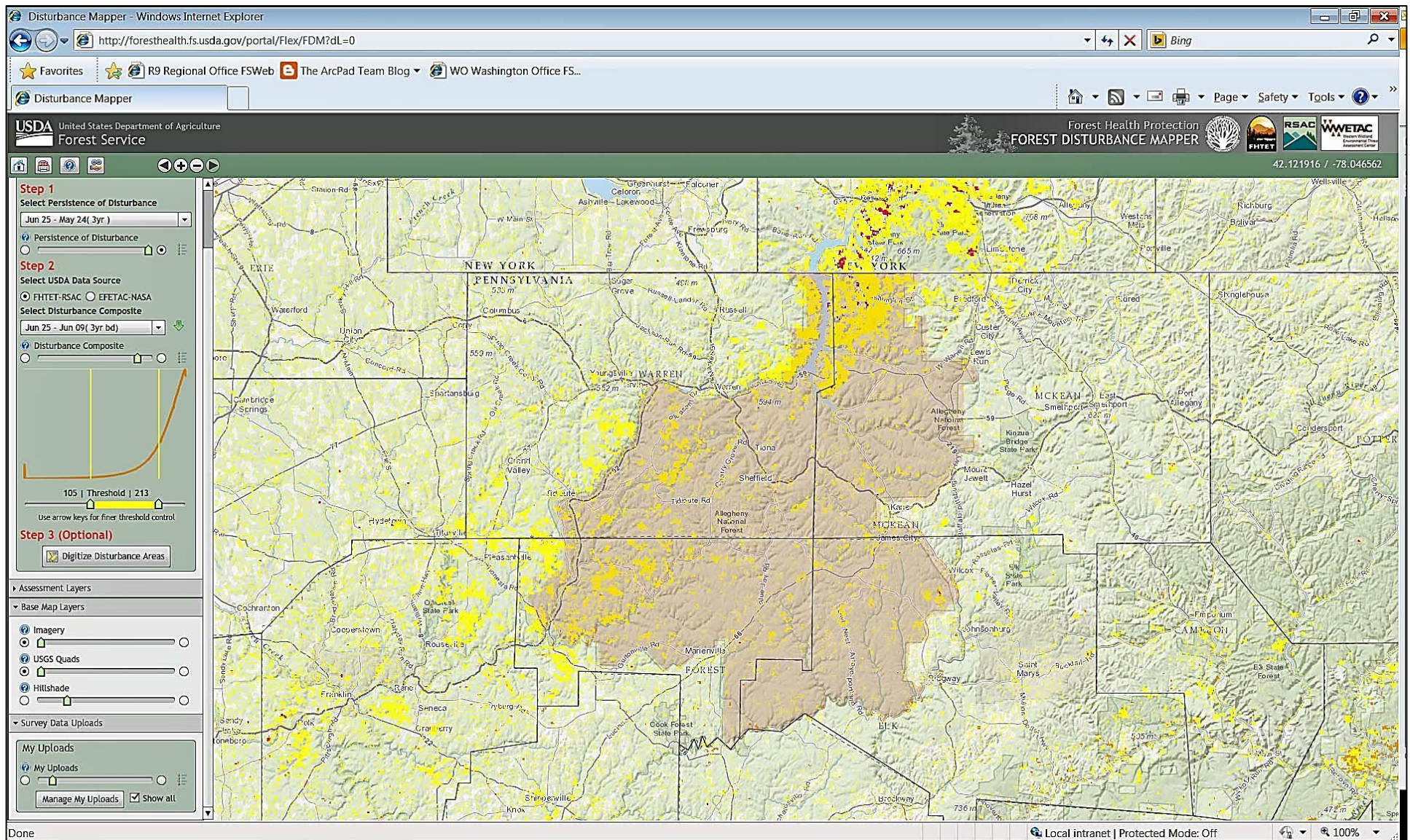


**Figure 9. Location of disturbances on the Allegheny National Forest derived from the Forest Disturbance Mapper that proved to be disturbances other than gypsy moth defoliation - June 2013 – see Table 1 for results of all sites visited.**



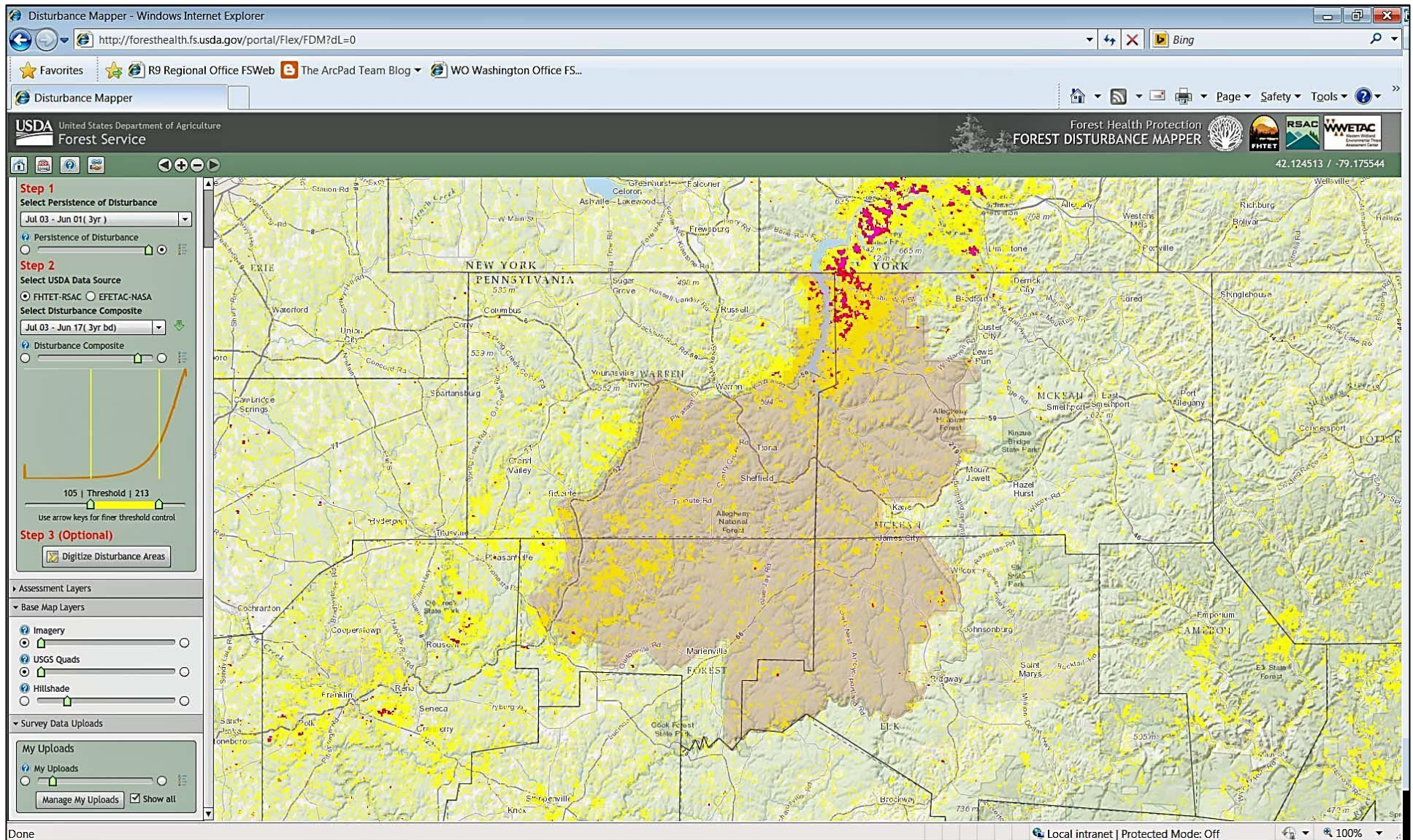


**Figure 10. Forest Disturbance Mapper image for 3 year disturbance composite: Jun 25 – Jun 09.**



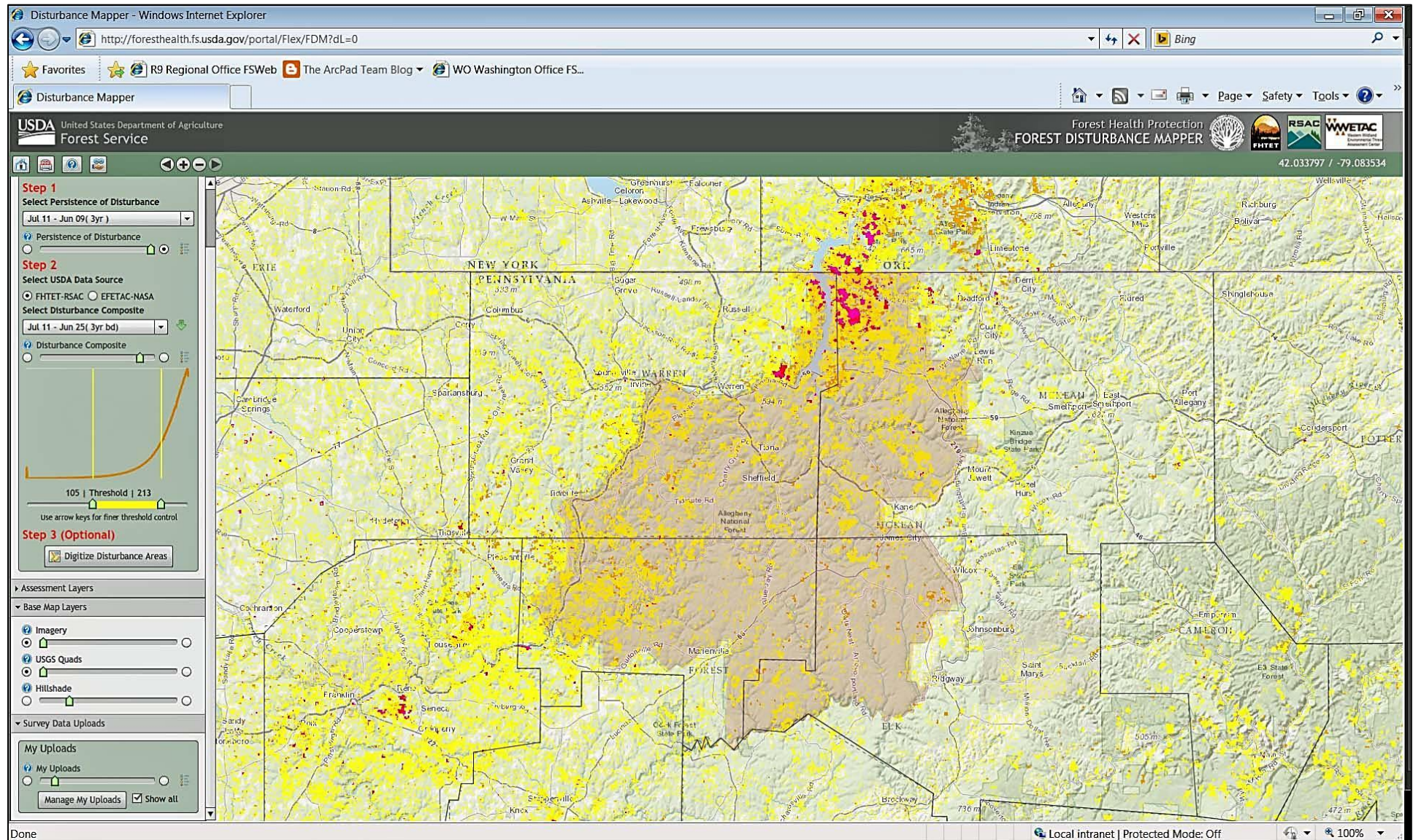


**Figure 11. Forest Disturbance Mapper image for 3 year disturbance composite: Jul 03 – Jun 17.**



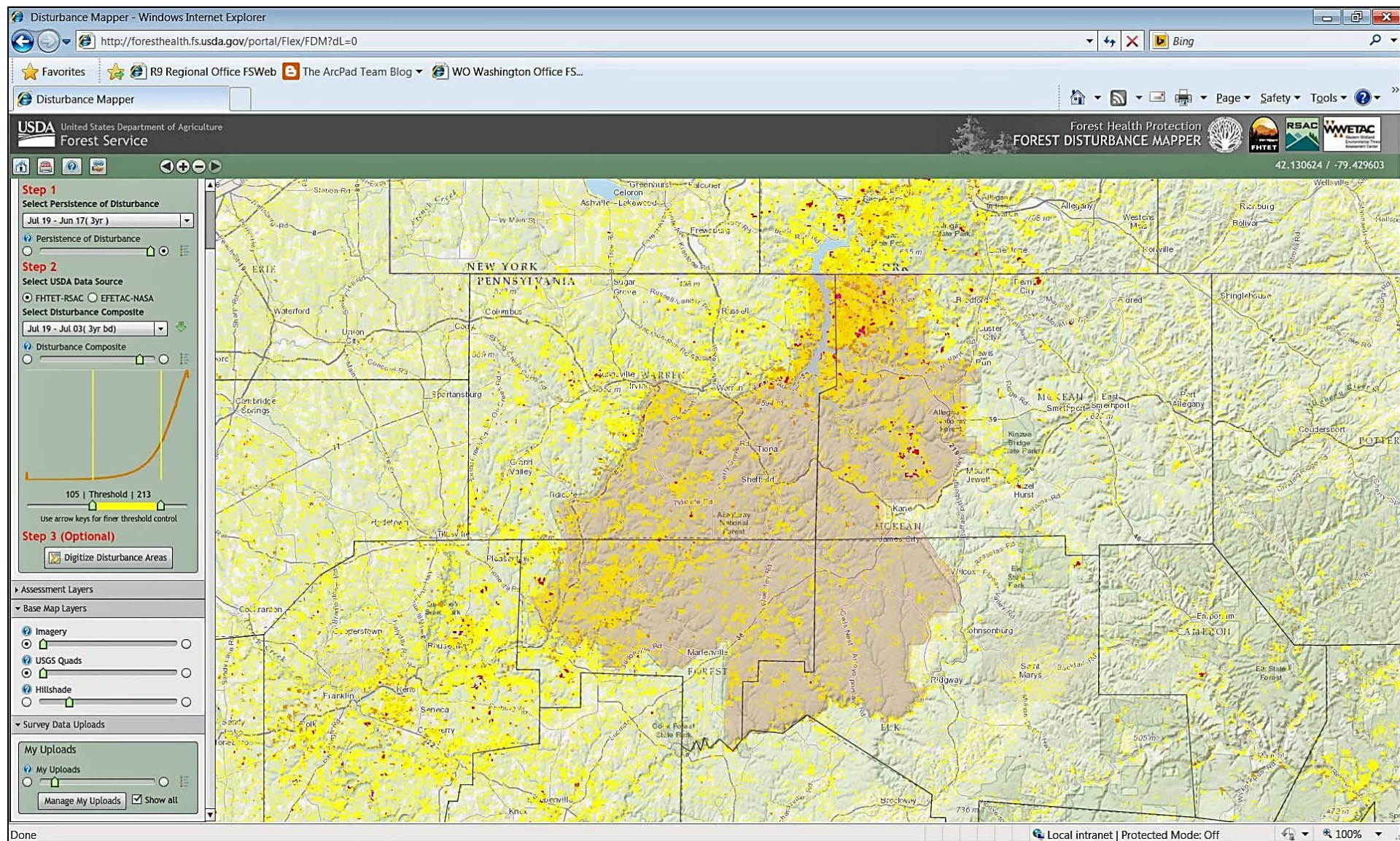


**Figure 12. Forest Disturbance Mapper image for 3 year disturbance composite: Jul 11 – Jun 25.**



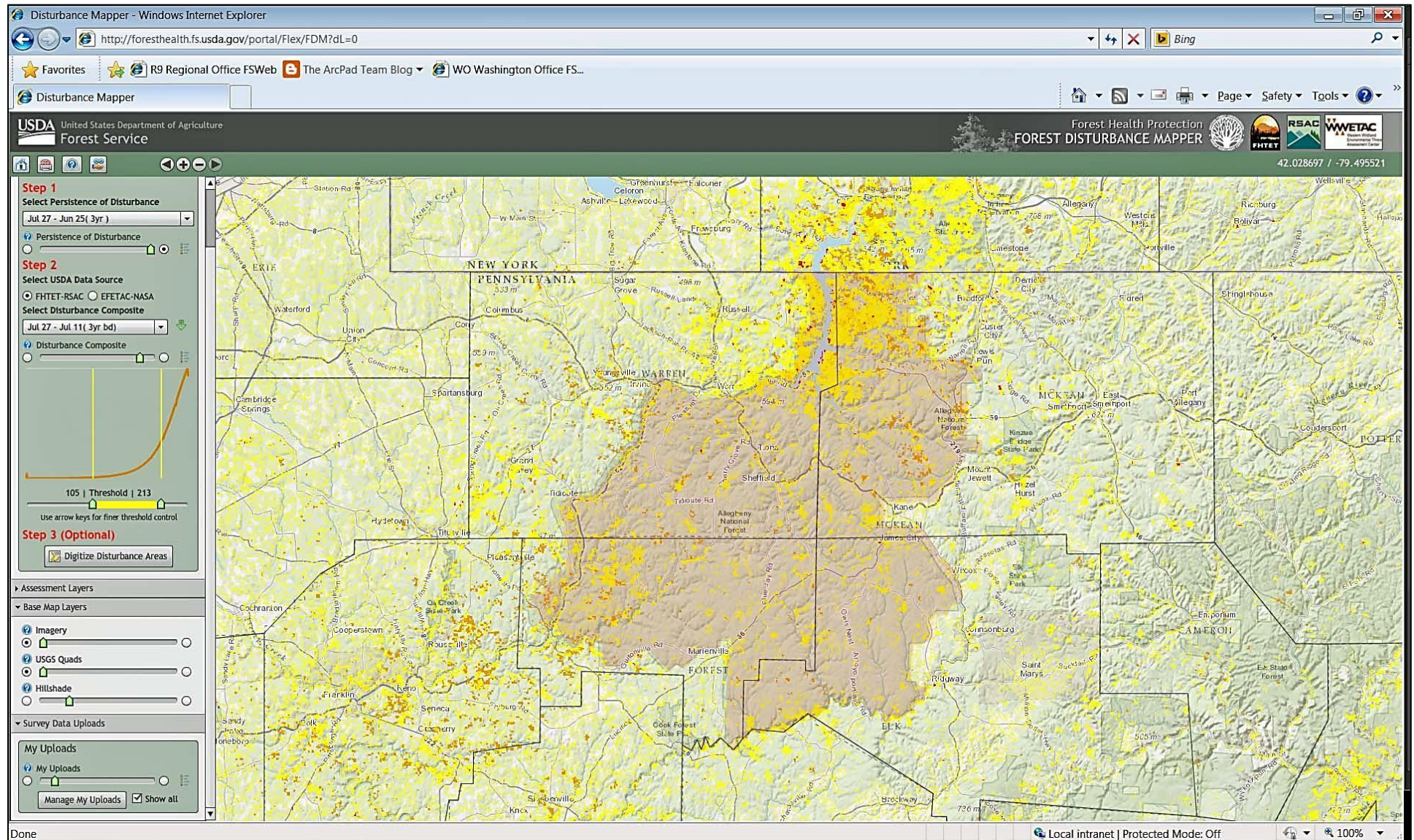


**Figure 13. Forest Disturbance Mapper image for 3 year disturbance composite: Jul 19– Jul 03.**



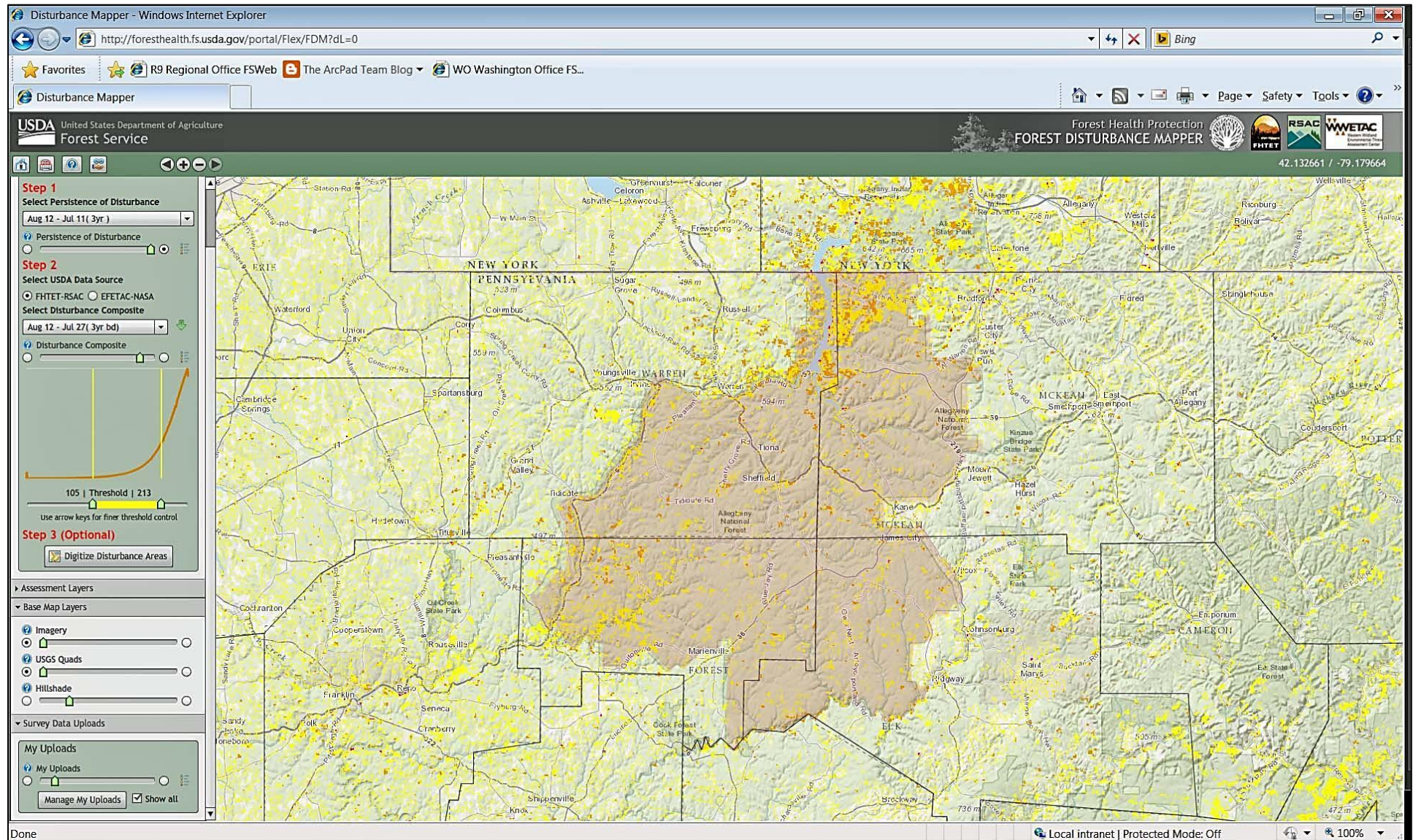


**Figure 14. Forest Disturbance Mapper image for 3 year disturbance composite: Jul 27– Jul 11.**





**Figure 15. Forest Disturbance Mapper image for 3 year disturbance composite: Aug 12– Jul 27.**





**Figure 16.**

**Location of the Forest Disturbance Mapper digitized polygons and ground truthing points on the Allegheny National Forest, PA, June 2013; and the 2013 Pennsylvania Aerial Survey results.**

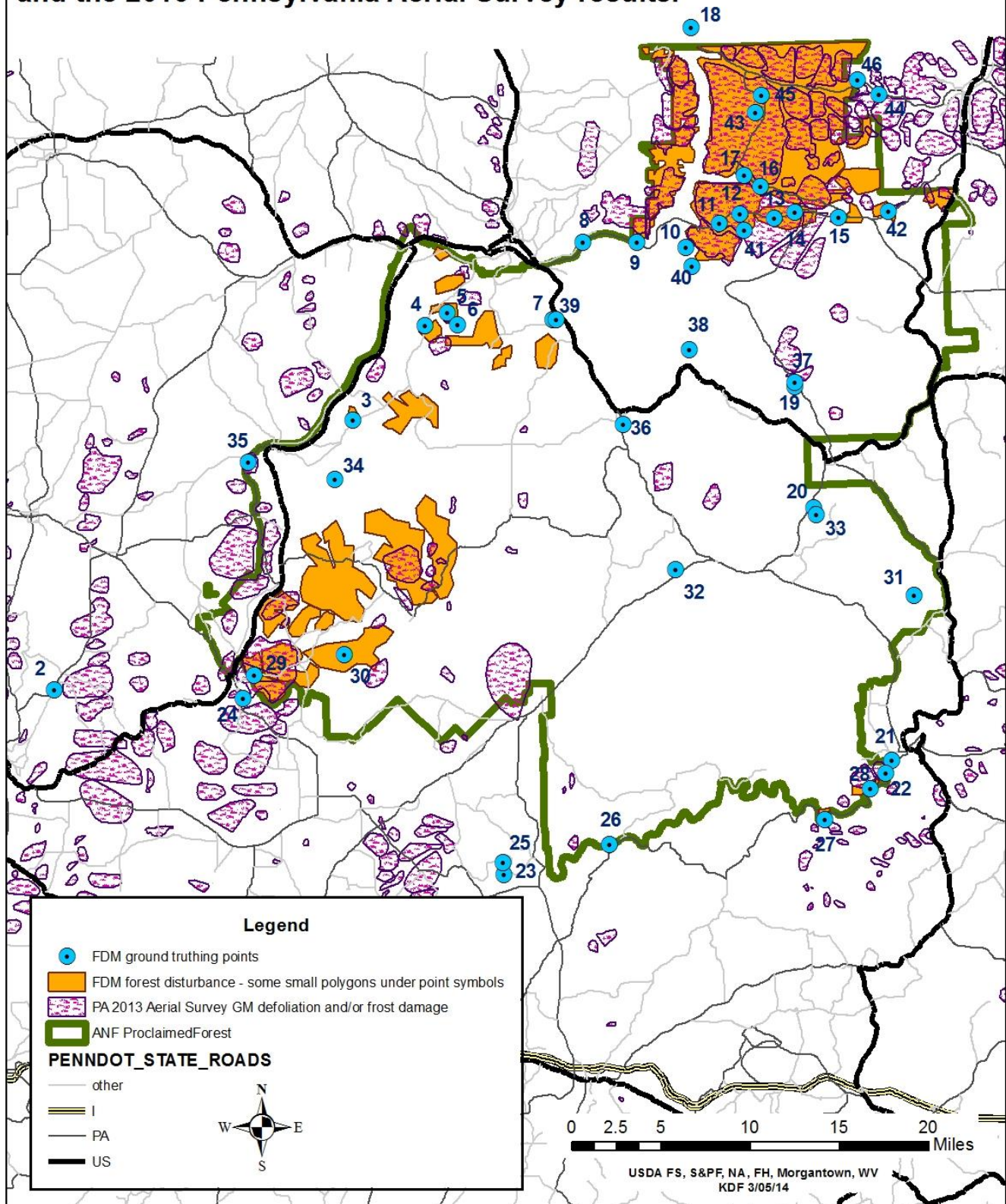




Figure 17-Allegheny National Forest gypsy moth egg mass survey locations, 2013.

